EVALUATION OF OPTIMAL POWER SUPPLY OPTION FOR A LARGE-SCALE FLOUR MILLING FACTORY IN NIGERIA

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ORIGINAL RESEARCH

Abstract— The study aimed to determine the optimal power supply model for large scale flour milling factory in Nigeria among available options such as the grid and on-site power generation, using temporal primary data from an existing standard factory. The aim was achieved using methods comprising: direct observation to identify the existing power supply options for the factory; NEPLAN Power System Analysis software to evaluate load flow parameters and grid kW losses; and adapted mathematical procedure to obtain model values such as the energy per ton of flour produced; annual costs of power plant installation, maintenance, fuel (diesel and gas), and personnel to obtain production cost of electrical energy consumed from a given energy source ($PCEE_{a,es}$). The results established that: factory's mini grid design is standard as load flow was normal and loading of main elements ranged between 35 and 52%; range of monthly electricity used per ton of milled product is (48.8, 96.7) kWh at an average 72.29 kWh/ton; range of monthly electricity supplied to the factory, with the consideration of grid losses is (1.757, 3.192) MWh and at an average of 2.5 MWh. Furthermore, determined average monthly production costs are: ₦101.176 million for gas-based electricity; ₦178.019 million for diesel-based; and ₦141.393 million for township Distribution Company-based supply. Consequently, power supply using gas fuel is the optimal option for a standard flour milling factory in Nigeria.

Keywords— flour industry, mini-grid, power generation, energy-per-ton.

1 INTRODUCTION

Power generation, transmission, and distribution systems make up an electric power system. Electrical distribution systems are responsible for distributing electrical energy for residential and industrial purposes (Melodi and Ale, 2023). The most important and lifeline of any business viability is the consistent energy supply at fair price (Wang, 2014). The use of electricity covers each element of human undertaking however its control and green use in some of the industries continue to be a query that has not yet properly investigated (Sola and Mota, 2020). Over a decade ago, the majority of Nigeria's energy production came from fossil fuels, which were considered unsustainable in the existing backdrop of global economy (Aderemi *et al*., 2009). Additionally, the cost of these energies to run many industries is continuously rising, which has an impact on profitability and return on investment (Aiyedun *et al*., 2008).

The use of electrical energy is essential to the advancement of any country and is associated with robust economic growth (Kaseke and Hosking, 2013). Accelerated and beneficial economic expansion requires a thriving and well-functioning industrial sector. In the present-day economy where industrialization is gaining ground and mass production becomes necessary for both exports and domestic consumption, electricity emerged as the key component that boosts the productivity and efficiency of other production inputs, particularly labor (Yahaya *et al*., 2015). Inputs, particularly labor and capital (Ezeh and Nnadi., 2016) (Yahaya *et al*., 2015). Over the years, Nigeria industrial development has been frustrated by a plethora of problems, pinnacle among them is the epileptic nature of electricity supply (Theophilus *et al*., 2016).

Despite diverse government-initiated policies, available data indicate that the industrial sector is growing slowly and one of the factors responsible for this to a significant degree is the low energy consumption. In Nigeria, only 10 percent of manufacturing concerns could operate at 48.8 percent of installed capacity, 60 percent of operating companies could barely cover their average variable costs, and 30 percent of operating companies were forced to shut down due to insufficient electricity supply, according to a survey in 2006 (Ogunjiobi, 2015). The sustainability of these industries depends on informed solutions on economically effective power supply options.

A modern economy cannot function without energy. The erratic power supply to the manufacturing industries and also, its adverse effect on machines and production output have necessitated the manufacturing industries operating in the country to opt for on-site power generation using available fuel sources. Therefore, there is need for the identification of the available energy sources of the selected flour milling company to evaluate the optimal power supply option. The manufacturing industries in Nigeria are reportedly facing its worst challenge due to inadequate electrical supply. An average Nigerian company has announced power outages or voltage fluctuations almost seven times a week, each lasting four to five hours. This results in significant costs

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Section B- ELECTRICAL/COMPUTER ENGINEERING & RELATED SCIENCES
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for the company due to lost production, lower returns on the investment and increased business uncertainty are the overall effects. Due to this, Nigeria's economy has become less attractive to foreign investors and has significantly reduced its potential for growth (Adeola, 2005). Hence, there is need to address the challenges highlighted. Thus, the aim of this study is to identify the energy sources of a large-scale Flour Milling Company in Nigeria, evaluate and determine the optimal power supply option. This study focused on the identification and assessment of the existing power supply options, evaluation of energy per ton of flour produced and production cost of electrical energy consumed from the energy sources to determine the optimal power supply option for the selected flour milling company.

The problem of Nigeria's perennial erratic power supply is known (Aremu, 2019; Olukoju, 2004; Ishaq et al., 2022). Nigeria has the largest population without electricity globally, which has resulted in a four percent decline in GDP (Onyenwe, 2022). This problem compelled business owners and industrial facilities to invest in local small, medium, and large-scale electric power generation in order to prevent production, equipment, machinery, and appliance failures. Due to the increased production costs resulting from these additional investments, local products are finding it more difficult to compete on price with their imported counterparts. This has also led many business owners and entrepreneurs to relocate from Nigeria to nearby nations in search of more lucrative business environments (Akiri *et al.*, 2015). Optimal local power generation solutions in industries becomes a problem to be addressed by local studies for specific industries as the flour mills that has huge market in the country.

In view of this study, optimization requires the determination of the best value of a given function (in this case – minimum electricity generation costs) known as the objective function, subject to a set of stated constraints placed on the variables concerned (Alena *et al.*, 2022)(Seung-Ju and Yourim, 2020)(Haruna *et al.*, 2017). The elements that make up the expenditure of a power plant include: cost of Fuel, cost of maintenance and cost of personnel. For the purpose of this study, operational characteristics a selected and representative flour milling factory was considered. The operations are cleaning of the raw/dirty wheat and milling of the cleaned wheat in to various brand of flour, semovita and bran as the by-product. The factory has 3 wheat mills (A, B, C) with capacities of 1000 t/day, 750 t/day and 500t/day respectively, and daily peak loads of 2.8MW, 1.8MW and 1.5MW respectively to produce flour two brands and semolina from wheat.

During the wheat cleaning and milling process, a lot of electric machines of different capacities and ratings ranging from 0.55 kW to 132 kW are put into operation to aid the cleaning and milling process. All these machines fed from the electrical energy generated locally by the factory using 3x3 MW gas and 2x4 MW gas-diesel hybrid generators depicted in Figure 1. The generators feed the mills' step-down transformers at 11 kV, which step the voltage down to 0.415 kV to power the milling machines and other factory loads. From the onset, the factory was not connected to available 33 kV township distribution company's (DisCo's) feeder.

(a)

(b)

Figure 1: a) Gas; b) Hybrid Engine

2 METHODOLOGY

2.1 Identification and Assessment of the Existing Power Supply Options of the Selected Flour Milling Company

Data and configuration of the power supply network were obtained from the power station of the selected flour milling factory and on-site survey. The data involve types and parameters of the installed generation, possible DisCo feeder voltage, supply frequencies, measured peak loads of the mills as shown in Tables 1, 2 and 3 respectively.

Load flow parameters were evaluated using NEPLAN software and Newton Raphson algorithm to obtain 11kv supply grid kw losses and voltage profile. These include factory daily grid losses at peak loads – $\Delta E_{l.d.max}$. Consequently, the actual daily grid loss ($\Delta E_{l.d}$) would consider the daily load factor as in equation 1.

$$\Delta E_{l.d} = LF \times \Delta E_{l.d.max} = LF * \Delta P_{l,peak} * 24 \qquad (1)$$

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where LF is load factor of daily load curve; $\Delta P_{l,peak}$ is technical grid losses when grid operates only at peak load.

In the absence of a daily load curve model, LF could be addressed as in equation 2.

$$LF = \frac{E_{emp}}{E_{max}} = \frac{E_{emp(\Delta t)}}{P_{peak} * \Delta t},$$

$$\Delta t = NoWpM * NoDpW * NoHpD \quad (2)$$

where E_{max} is energy consumed at peak load for the same period; $NoWpM$ is the number of weeks per month; $NoHpD$ is the number of hours per day; $NoDpW$ is the number of days per week; Δt data period considered (hrs), $E_{emp(\Delta t)}$ is empirical energy consumed for the given data period observed at the power station of the factory.

Annual grid energy losses $\Delta E_{l.a}$:

$$\Delta E_{l.a} = 356\, \Delta E_{l.d} \quad (3)$$

Monthly grid energy losses $\Delta E_{l.m}$:

$$\Delta E_{l.m} = \frac{\Delta E_{l.a}}{12} \quad (4)$$

The power supply network diagram is as shown in Figure 2, created using NEPLAN Power System Analysis (PSA) software.

2.2 Evaluation of the Energy Per Ton of Flour Produced

The energy per ton of the flour produced was evaluated using the following mathematical procedure, based on energy and power balance concepts:

(i) Electricity consumed by factory load in a given month m (E_m) is defined as:

$$E_m = \sum_{i=1}^{3} E_{m,i}\,;\ E_{m,i} = \sum_d E_{d,i}\,; d \in m \quad (5)$$

where $E_{m,i}$ is electricity consumed on i-th mill in month m; $E_{d,i}$ is daily electricity obtained from installed energy meters in a day d, on i-th mill.

(ii) Electricity used per ton of i-th mill in a given month m ($\boldsymbol{E_{pt(m,i)}}$) is defined as:

$$E_{pt(m,i)} = \frac{E_{m,i}}{Qty_{m,i}} \quad (6)$$

where ($Qty_{m,i}$) is the monthly tons of product produced in the i-th mill.

(iii) Total electricity used per ton for milling in month m (Ept_m) is defined as:

$$Ept_m = \frac{\sum_{i=1}^{3} E_{m,i}}{\sum_{i=1}^{3} Qty_{m,i}} \quad (7)$$

(iv) Electricity supplied to the factory in month m ($E_{f(m)}$) is defined as in equation 8:

$$E_{f(m)} = E_m + \Delta E_{l,m} = EG_m \quad (8)$$

$\Delta E_{l,m}$ is the grid losses in month m, obtained using load flow simulation; EG_m is the energy generated in month m.

(v) Energy generated for a given year a (EG_a)

$$EG_a = \sum EG_m, m \in a \quad (9)$$

Table 1: The Transformer Ratings and Peak Load Profile

MILL	Transformer Ratings (MVA)	Voltage Level (KV)	Peak Load (MW)	P (KW)	Q (Kvar)	S (KVA)	PF (Cos θ)
A	6	11/0.415	2.8	2390	507	2443.184	0.98
B	3	11/0.415	1.8	1430	430	1493.251	0.99
C	3	11/0.415	1.5	1050	201	1069.065	0.98

Table 2: Line parameters

Bus	Cable Length	Cable Size	No of Lines	Cable Distance	Material	Layout	Resistance $\boldsymbol{\Omega/km}$	Reactance$\boldsymbol{\Omega/km}$
0-1	0.5km	1 x 400mm2	3	300mm	Cu	In air	0.06	0.07
0-2	0.5km	1 x 400mm2	3	300mm	Cu	In air	0.06	0.07
0-3	0.5km	1 x 400mm2	3	300mm	Cu	In air	0.06	0.07

Table 3: Existing Power Option of The Milling Company

Generator Type	Quantity	Capacity (MW)	Output Voltage (KV)
Watsila Hybrid Engine	2	4	11
Jenbacher Mono Fuel Engine (Gas)	3	3	11

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2.3 Determination of the Optimal Power Supply Option

Determination of the optimal power supply option involves the evaluation of production cost of electrical energy ($PCEE$) for the energy sources.

2.3.1 Production Cost of Electrical Energy Consumed

The production cost of electrical energy consumed was calculated using equation 10:

$$PCEE_{a,es} = CoPP_{a,es} + CoF_{a,es} + CoM_{a,es} + CoP_{a,es} = \sum_{m=1}^{36} PCEE_{m,es} \quad (10)$$

where $PCEE_{a,es}$ is the production cost electrical energy consumed in a year for energy source es; $CoPP_{a,es}$ is the annual capital cost of power plant; $CoF_{a,es}$ is the annual cost of fuel; $CoM_{a,es}$ is the annual cost of maintenance; and $CoP_{a,es}$ is the annual cost of personnel.

The condition of optimality is as in equation 11:

$$PCEE_{a,h} = min \quad (11)$$

Given:

(i) Number of personnel (NoP):

$$NoP = 3 \quad (12)$$

(ii) Annual work hours (AWH):

$$AWH = \sum_{j=1}^{NoP} h_j = 8760hrs; \quad h_j = constant \quad (13)$$

Where h_j is the AWH of the j-th successive power plant personnel i.e

$$h_1 = h_2 = h_3 = \frac{AWH}{NoP} = \frac{8760}{3} = 2920\ hrs \quad (14)$$

(iii) Number of shifts per year (NoS_a):

$$NoS_a = \frac{h \times NoP}{NoHpS} = \frac{2920 \times 3}{12} = 730\ Shifts \quad (15)$$

Where $NoHpS$ is the number of hours per shift.

(iv) Number of shifts per day (NoS_d):

$$NoS_d = \frac{NoS_a}{365} = \frac{730}{365} = 2 \quad (16)$$

(v) Number of shifts per power plant personnel (NoS_pP):

$$NoS_pP = \frac{NoS_a}{NoP} = \frac{730}{3} = 243.33 \cong 243\ shifts \quad (17)$$

(vi) Wage per hour (WpH):

$$WpH = \frac{WpP_a}{h} = \frac{WpP_m \times NoM}{h} \quad (18)$$

Where WpP_a and WpP_m are annual wage and monthly wage per personnel respectively, NoM is number of months – 12, and WpP_m is ₦215,000 (Factory data)

$$WpP_a = WpP_m \times NoM \quad (19)$$

(vii) Annual cost of power plant personnel (CoP_a):

$$CoP_a = NoP \times WpP_a = NoP \times WpP_m \times NoM \quad (20)$$

Alternatively, $CoP_a = NoP \times WpH \times h$ (21)

(viii) In the absence of empirical data of monthly cost of maintenance (CoM_a) variable along with other monthly cost data. Let coefficient of maintenance be β as defined in equation (22):

$$\beta = \frac{CoM_a}{EG_a} \quad (22)$$

where CoM_a and EG_a are annual cost of maintenance and annual energy generated respectively.

Given availability of data of CoM_a and EG_a for short term (three consecutive years), statistically on the average, β is evaluated as β_{av} as in equation 23:

$$\beta_{av} = \frac{\sum_{a=1} \frac{CoM_a}{EG_a}}{\sum_{a=1} a}, 3 \leq a < 5 \quad (23)$$

Consequently, cost of maintenance in month m (CoM_m) can be evaluated using equation 24:

$$CoM_m = \beta_{av} \times EG_m \quad (24)$$

Where EG_m and β_{av} are the monthly energy generated and average value of coefficient of maintenance respectively.

(ix) Annual Capital/Installation Cost of Power Plant ($CoPP_a$):

$$CoPP_a = \frac{PVP}{Service\ Life} = \frac{\sum(NoU_i \times UP_i)}{Service\ Life} \quad (25)$$

Where PVP is the purchase and installation value of plant; NoU is the number of units; UP is the unit price; and i is the type of plant.

$$CoPP_a = CoPP_{a\,(g)} + CoPP_{a\,(hbd)} \quad (26)$$

$$CoPP_{a\,(g)} = \frac{\sum(NoU_g \times UP_g)}{Service\ Life} \quad (27)$$

$$CoPP_{a\,(hbd)} = \frac{\sum(NoU_{hbd} \times UP_{hbd})}{Service\ Life} \quad (28)$$

Where NoU_g is the number of units of gas generators; UP_g is the unit price of gas generator; NoU_h is the number of units of hybrid generators; and UP_{hbd} is the unit price of hybrid generators.

(x) Average Monthly cost of power plant ($CoPP_m$):

$$CoPP_m = \frac{CoPP_a}{NoM} = \frac{₦198,018,460.3}{12} = ₦16,501,538.4 \quad (29)$$

(xi) Monthly cost of personnel (CoP_m):

$$CoP_m = WpP_m \times NoP = ₦215,000 \times 3 = ₦645,000:00 \quad (30)$$

(xii) Monthly production cost of electrical energy ($PCEE_m$):

$$PCEE_m = CoPP_m + CoF_m + CoM_m + CoP_m \quad (31)$$

(xiii) Monthly production cost of electrical energy using gas fuel ($PCEE_{m(g)}$):

$$PCEE_{m(g)} = CoPP_m + CoF_{m(g)} + CoM_m + CoP_m \quad (32)$$

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Where $CoPP_{m(g)}$ and $CoF_{m(g)}$ are the monthly cost of gas power plant and monthly cost of gas fuel respectively.

(xiv) Monthly production cost of electrical energy using diesel fuel ($PCEE_{m(d)}$):

$$PCEE_{m(df)} = CoPP_m + CoF_{m(df)} + CoM_{m(df)} + CoP_{m(df)} \quad (33)$$

Where $CoPP_{m(d)}$ and $CoF_{m(d)}$ are the monthly cost of diesel power plant and monthly cost of diesel fuel respectively.

(xv) Monthly cost of electrical energy using Disco ($PCEE_{m(EKEDC)}$):

$$PCEE_{m(EKEDC)} = CoE_{m(EKEDC)} \quad (34)$$

Where $CoE_{m(EKEDC)}$ is the cost of electrical energy from EKEDC

3 RESULTS AND DISCUSSIONS

3.1 IDENTIFICATION AND ASSESSMENT OF THE EXISTING POWER SUPPLY OPTIONS OF THE SELECTED FLOUR MILLING COMPANY.

The major sources of energy required in the wheat flour mills are electrical and manual energy, and flour production requires three processes: cleaning, milling, and packing. These procedures are carried out in continuous and repetitive cycles, and the energy inputs into each operation have been taken into account. Schema of Load flow obtained is presented in Figure 2. The values of the parameters obtained at peak load are summarized in Tables 4 and 5. Bus voltages are within $\pm 5\%$ of nominal value; loading of main elements range between 35 and 52%, indicating that all the load flow parameters would be within standard permissible values at peak load. Expected maximum grid losses would be 0.1445 MW and corresponding monthly energy losses would not exceed 56,961.9 kWh, since the supply point is the same for all options of power supply, the network response would be same and no issues expected.

3.2 EVALUATION OF ENERGY PER TON OF FLOUR PRODUCED

The energy consumed by the factory load, used per ton of the i-th mill and the mills, as well as the electricity supplied to the factory were computed and analyzed.

Figure 3 presents the temporal electricity consumed by the factory loads i.e. mills A, B and C respectively in given month m during the data period (January 2020 to December 2022). From the chart, it can be seen that the electrical energy consumption was the highest in mills A, followed by B, and then C. The electricity consumption is proportional to their respective design capacities. The electrical energy consumed ranges are (820196, 1428984) kWh, (384539, 962728) kWh, and (349792, 856714) kWh respectively for each of the mills.

Figure 4 presents the electricity used per ton of i-th mill in month m and the total electricity used per ton for milling in month m. It shows that E_{pt} for mills A, B, C and the entire factory milling ranges are (65.5, 87.1) kWh/ton, (60.9, 96.7) kWh/ton, (48.8, 96.5) kWh/ton and (65.6, 86.4) kWh/ton respectively. Furthermore, the E_{pt} is expectedly not time correlated. These ranges implied an average 72.29 kWh/ton for the factory.

Figure 5 presents the determined temporal electricity supplied to the factory in the data period. It shows that with the consideration of grid losses, monthly electricity use ranged from 1,757,084.8 kWh to 3,192,525 kWh and an at average 2,496,691.47 kWh.

3.3 DETERMINATION OF OPTIMAL POWER SUPPLY GENERATION

Table 6 presents the annual energy generated, cost of maintenance and the average values of the coefficient of maintenance for the data period. It shows that energy generated ranges from 28282157.90 kWh to 31373617.80 kWh at an average 29447382.80 kWh. The annual cost of maintenance also ranged from ₦17,111,141.30 to ₦23,017,556.25, at an average ₦19,904,733.68. This could be as a result of the aging, wear and tear of the generators parts.

3.3.1 Cost of Power Plant Personnel

Annual cost of power plant personnel is the product of number of months, number of personnel and monthly wage per personnel as shown in Table 7.

3.3.2 Cost of Power Plant

Average monthly capital cost of power plant is the quotient of annual cost of power plant and number of months as shown in Table 8.

Figure 6 presents the monthly production cost of electrical energy for the energy sources in the data period. It shows that production of electrical energy using gas fuel ranges from ₦57,016,856:00 to ₦172,376,786:25 at an average ₦101,176,161:60; diesel fuel ranges from ₦116,772,536:20 to ₦260,235,249:34 at an average ₦178,018,770:14; and possible EKEDC supply ranges from ₦94,513,567:20 to ₦186,585,829:32 at an average ₦141,393,804:48. This indicated that production cost of electrical energy using diesel fuel was the highest, followed by EKEDC, and then gas fuel. Consequently, power supply using gas fuel is optimal.

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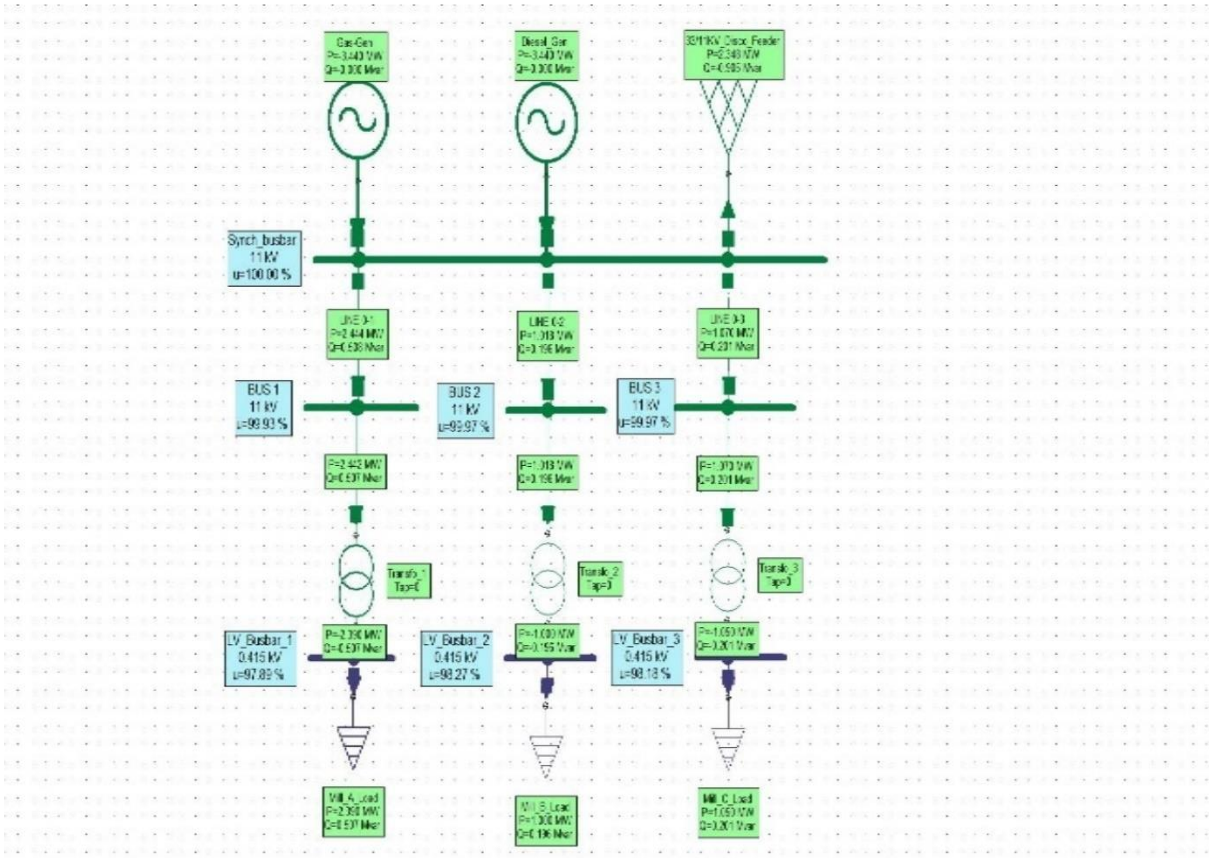

Figure 2: Factory's Main Power Supply Network Diagram and Load Flow of The Flour Milling Factory

Table 4: Node Results of Load Flow Analysis

	Node Name	P Load (MW)	Q Load (Mvar)	% PF	P Gen (MW)	Q Gen (Mvar)	%V	V (kV)
HV Bus	0	0	0	98	5.015	1.139	100	11
	1	0	0	98	0	0	99.98	10.98
	2	0	0	98	0	0	99.98	10.98
	3	0	0	98	0	0	99.99	10.99
LV Bus	1	2.39	0.57	98	0	0	97.54	0.401
	2	1.43	0.43	98	0	0	96.68	0.405
	3	1.05	0.201	98	0	0	98.21	0.408

Table 5: Branch Results of Load Flow Simulation, Load Factor, and Daily Line Losses

Bus	i	j	P (MW)	Q (Mvar)	I (kA)	$\Delta P_{l,peak}$ (MW)	% Loading	$\Delta E_{l.d.max}, kWh$	LF	$\Delta E_{l.d}, kWh$	$\Delta E_{l.m}, kWh$	$\Delta E_{l.a}, kWh$
HV	0	1	2.475	0.508	0.133	0.0004	42.11					
	0	2	1.469	0.430	0.08	0.0002	51.02					
	0	3	1.070	0.201	0.057	0.0001	36.28					
LV	1	1	2.390	0.507	3.516	0.085	40.72					
	2	2	1.430	0.430	2.13	0.039	49.78					
	3	3	1.050	0.201	2.514	0.0198	35.64					
Total						0.1445		3468	0.54	1,872.72	56,961.9	683,542.8

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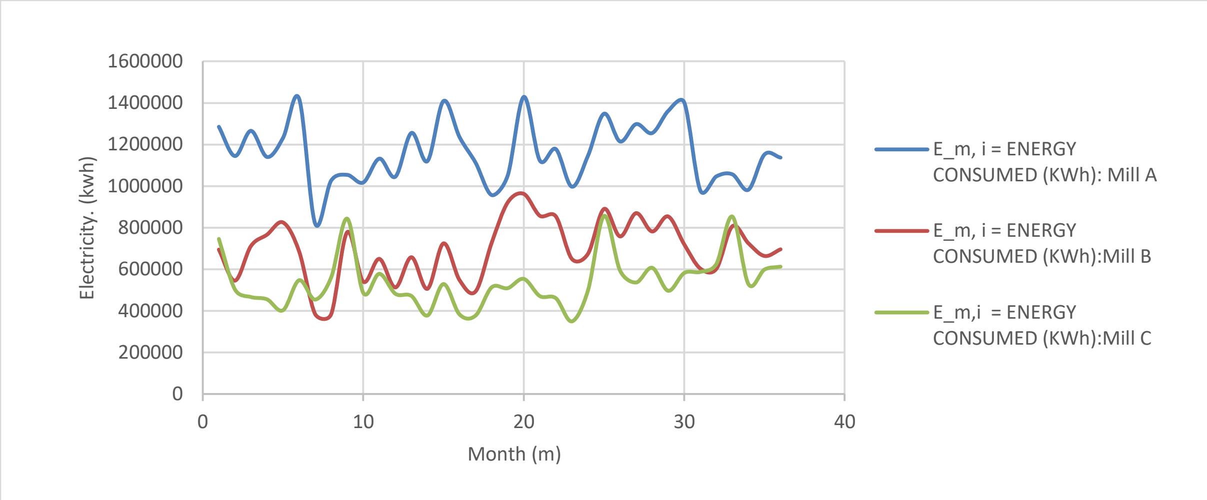

Figure 3: Monthly electricity consumed by mills A, B and C respectively in data period (36 months)

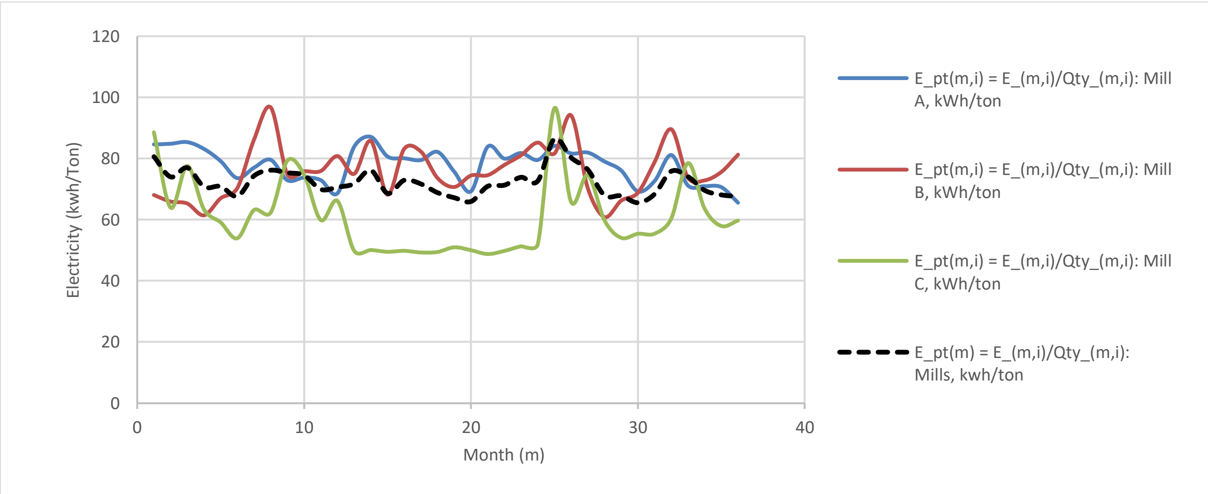

Figure 4: Monthly electricity used per ton of items produced in mills A, B, C respectively and the total electricity used per ton for milling in data period.

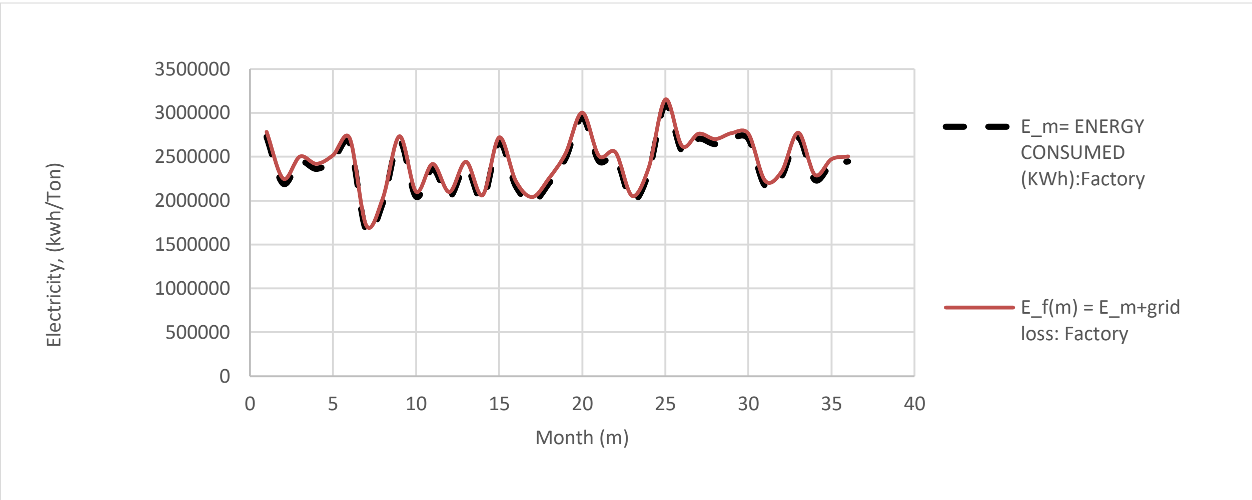

Figure 5: Monthly electricity supplied to the factory in data period.

Table 6: Annual Energy Generated and Cost of Maintenance for the Data Period.

Year		Annual Energy Generated EG_a (kWh)	Annual Cost of Maintenance CoM_a(₦)	Annual Coefficient of Maintenance β_a(₦/kWh)
2020		28282157.90	**₦17, 111, 141. 30**	**0. 62₦/kwh**
2021		28776372.80	**₦19, 585, 503. 48**	**0. 68₦/kwh**
2022		31373617.80	**₦23, 017, 556. 25**	**0. 75₦/kwh**
Average Value (2020 – 2022)		29447382.80	**₦19, 904, 733. 68**	**0. 68₦/kwh**
Range 2020 - 2022	MIN	28282157.90	**₦17, 111, 141. 30**	**0. 62₦/kwh**
	MAX	31373617.80	**₦23, 017, 556. 25**	**0. 75₦/kwh**

Table 7: Annual Cost of Power Plant Personnel

NoP	h_j	WpP_m	NoM	WpP_a	WpH	CoP_a:
3	2920	₦215,000:00	12	₦2,580,000	₦883.56	₦7,740,000

Table 8: Average Monthly Capital Cost of Power Plant

NoU_g	UP_g	NoU_{hbd}	UP_{hbd}	*Service Life*	$CoPP_a$	NoM	$CoPP_m$
3	*₦709,370,850*	*2*	*₦916,128,328*	*20*	*₦198,018,460:3*	*12*	*₦16,501,538:4*

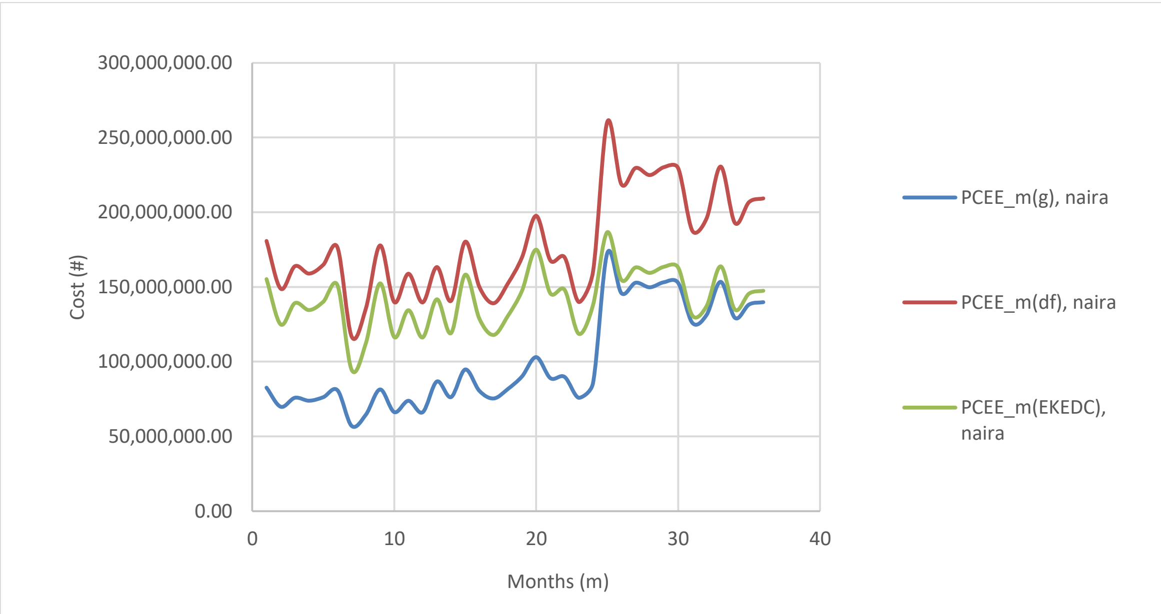

Figure 6: Monthly production cost of electrical energy for the energy sources in the data period.

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4 CONCLUSIONS

This work presented an analytical evaluation of optimal cost of electricity generation for the selected flour milling factory with daily production capacity of 2250 tons/day. The following conclusions can be made from an analysis of the results.

Neplan software and Newton Raphson Algorithm were deployed to simulate the load flow parameters. Load flow analysis established that standard large-scale factory mini grids are installed as all load flow parameters would be within standard allowable values at peak load. The highest grid losses anticipated are 0.1445 MW, and the associated monthly energy losses are estimated to be no more than 56,961.9 kWh. Since the supply point is the same for all power supply alternatives, the network response is anticipated to be the same, with no issues. The ranges of monthly electricity consumptions of the three mills of the factory are (820196, 1428984) kWh, (384539, 962728) kWh, and (349792, 856714) kWh respectively, and proportional to their respective design loads.

The range of monthly electricity used per ton for milling is (48.8, 96.7) kWh and an average 72.29 kWh/ton for the factory. range of Monthly electricity supplied to the factory, with the consideration of grid losses is (1.757, 3.192) GWh and at an average of 2.496 GWh. The annual cost of maintenance also ranged from ₦17,111,141.30 to ₦23,017,556.25, at an average ₦19,904,733.68. This could be as a result of the aging, wear and tear of the generators parts. Monthly production cost of electrical energy using gas fuel ranges from ₦57.02 to ₦172.377 million at an average ₦101.176 million; diesel fuel ranges from ₦116.772 to ₦260.235 million at an average ₦178.019 million; and township Distribution Company (DisCo) supply ranges from ₦94.514 to ₦186.586 million at an average ₦141.393 million. Consequently, power supply using gas fuel is the optimal option for a standard flour milling factory in Nigeria.

This work has been able to establish the optimal cost of power supply for the selected flour milling company; and provide the cost of power generation on per unit of produced items. These model values of obtained energy use parameters are applicable for planning mini grid designs and operations of prospective large scale flour milling factories in Nigeria.

5 RECCOMENDATIONS

It is advised that the factory upgrade to energy-efficient technology by replacing outdated machinery with energy-efficient alternatives, such as variable-speed drives and soft starters for high-capacity induction electric motors; integrate renewable energy, such as solar, to form an energy mix; and reuse waste heat to reduce energy consumption through the heat recovery system. Such measures will ensure cost-effective energy production and consumption within the factory.

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